An 'Enviro-Informatic' Assessment of Saginaw Bay, Phytoplankton: Characterization and Modeling of *Microcystis*

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INTRODUCTION

'Enviro-Informatics', Zebra Mussels, & *Microcystis*

Our comprehension of how coastal systems respond to disturbances and stressors requires 1) characterization from which ecological structure can be interpreted and 2) data-assimilative modeling from which system functionality and dynamics might be reproduced. However, the usefulness of data-generated information for our interpretation and prediction of stressor-disturbance 'outcomes' is contingent upon the quantitative approaches used to reproduce the complexity of biotic patterns and processes.Advancements in computer technologies have provided for computationally intensive statistical technologies to assist scientists in large-scale data manipulation/mining, pattern recognition, and information synthesis. This approach for assessing environmental-biotic interactions is termed, '*Environmental* (*Enviro*-) *Informatics*'.

Since the invasion of zebra mussels into Saginaw Bay during the early 1990s, annual, late-summer blooms of *Microcystis aeruginosa* have occurred. *Microcystis* can comprise a significant proportion of the Bay's late-summer phytoplankton assemblage and blooms are professed to threaten public health and the use of the Bay as a natural resource. Data-driven models based upon environmental/biotic influences and projecting the spatial/temporal fields of *Microcystis* are desirable tools from which to derive information for resource management and guide bloom mitigation efforts.

Here, adaptive and computationally-intensive statistical approaches are used to 1) characterize *Microcystis* biomass within the context of the overall assemblage; 2) delineate key factors regulating (holistic) phytoplankton and *Microcystis* patterns; and 3) develop models predicting phytoplankton and *Microcystis* biomass in relation to dynamic environmental constraints. Data assessed were generated in a NOAA-Great Lakes Environmental Research Laboratory study addressing the impacts of zebra mussel recruitment on the Bay's water quality and biota, 1990 to 1996

Saginaw Bay

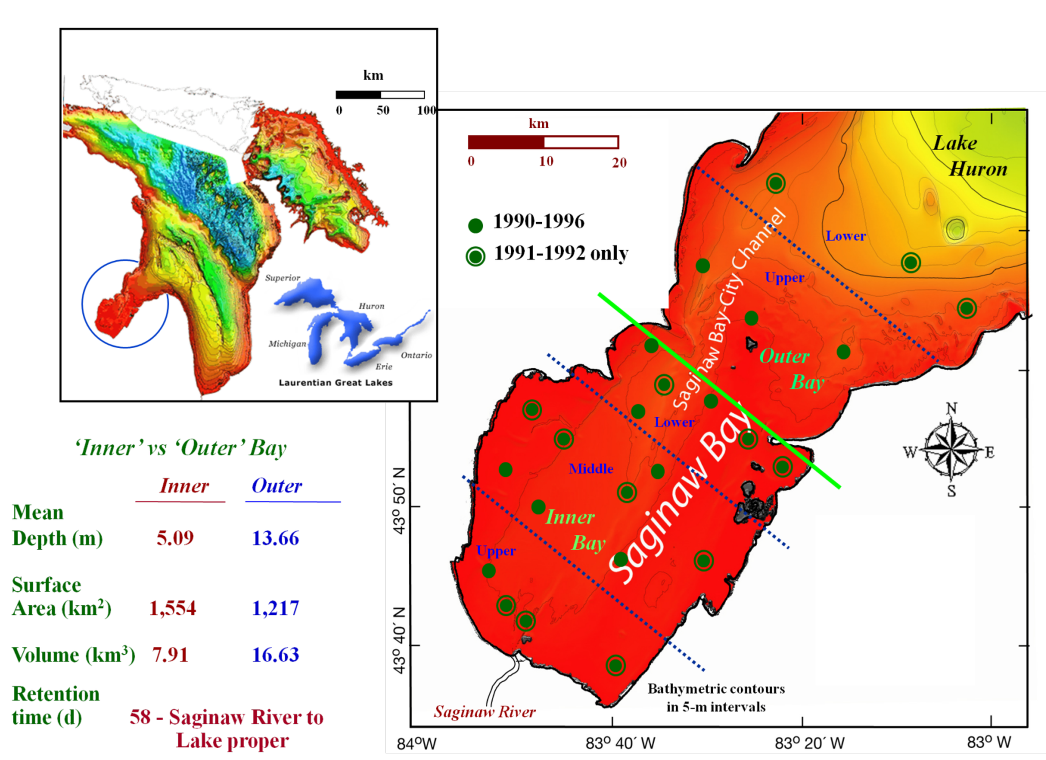


Figure 1. Sampling stations throughout Saginaw Bay. Inset figure places the Bay relative to the Great Lakes.

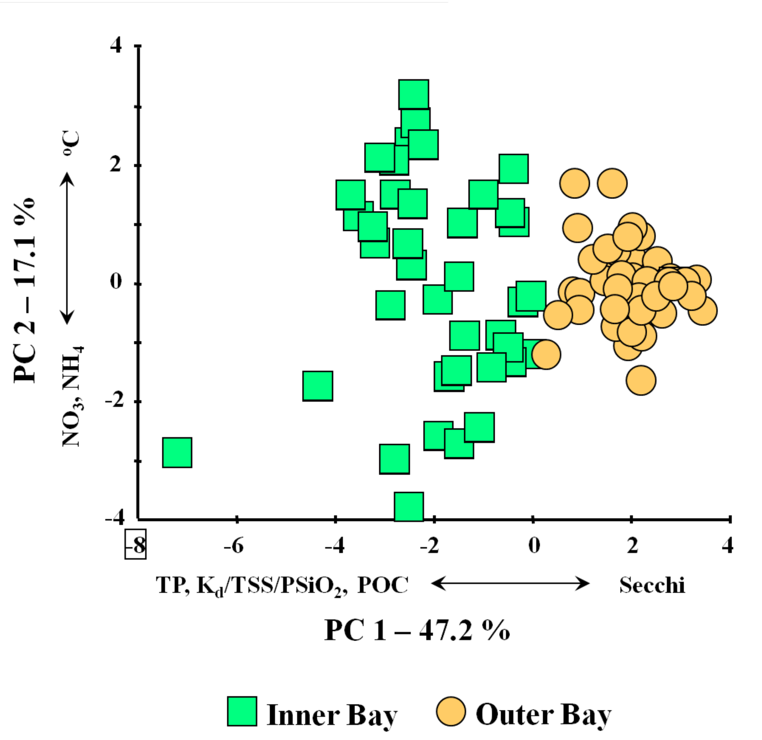


Figure 2. Principal components ordination of stations (denoted as a function of inner and outer Bays) based on physical/chemical variables.

Rank-Based) Phytoplankton Compositional Similarities

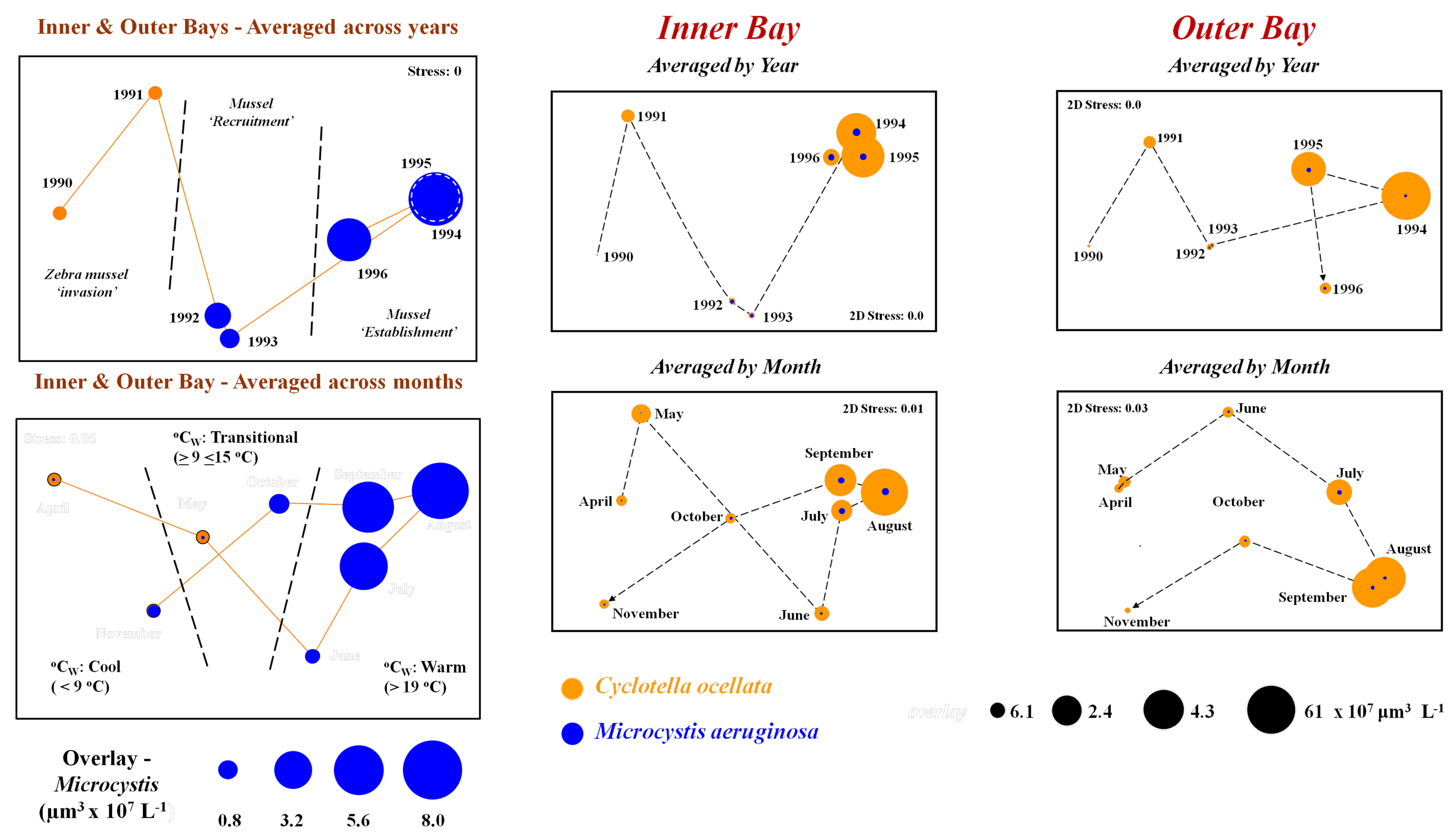
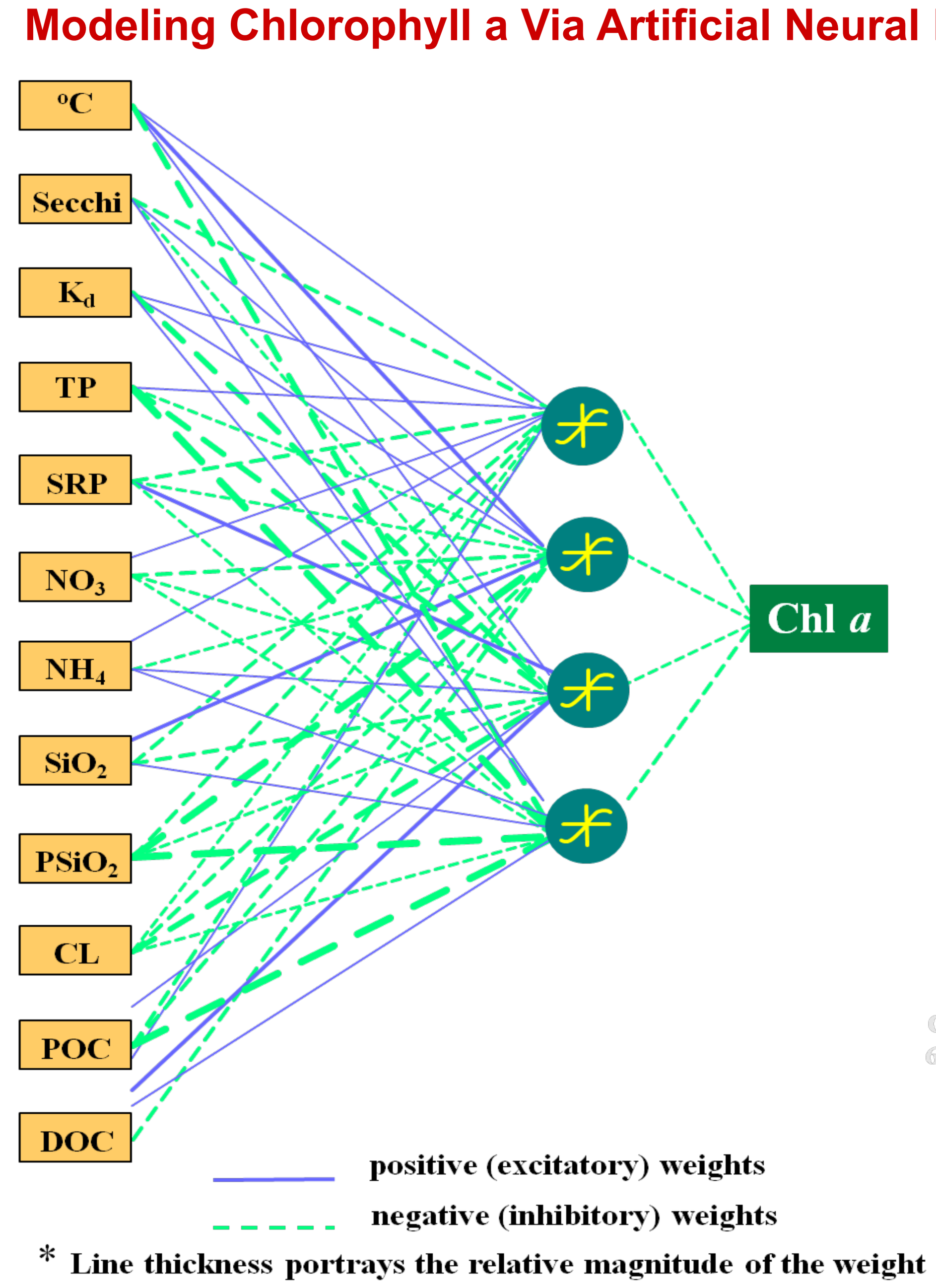
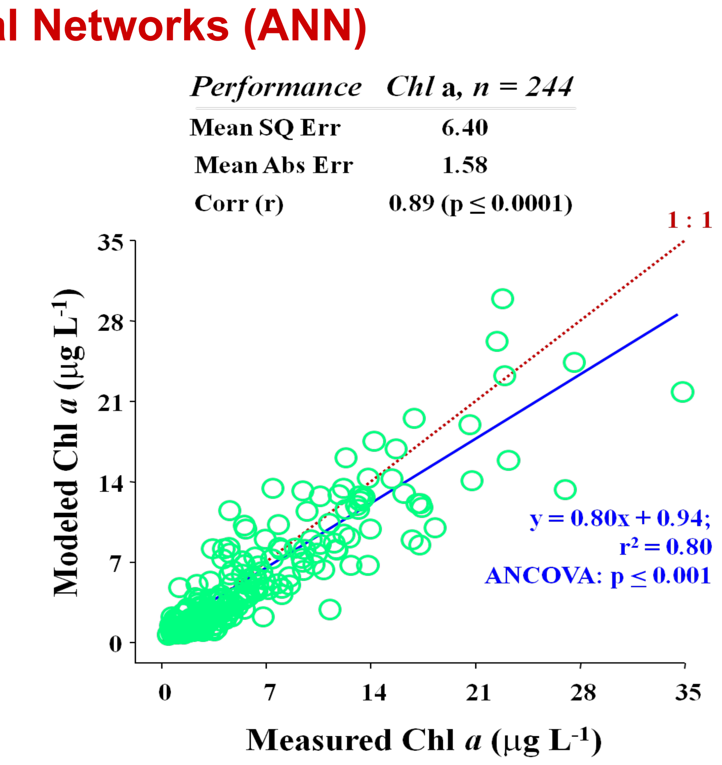


Figure 3. Multi-dimensional scaling ordinations of sampling stations based on Bray-Curtis similarities of phytoplankton biomass, averaged across sampling years and months. Absolute biomass for *Microcystis* is superimposed (as symbols of differing size) on ordination. Stations as a function of inter-annual groupings (top panel): 1990 & 1991, zebra mussel invasion; 1992 & 1993, mussel recruitment; 1994 to 1996, mussel establishment. Stations as a function of intra-annual groupings (bottom panel) reflecting seasonal periods of 'cool', 'transitional' and 'warm' temperature waters: < 9^{o}C, April and November; $\geq$ 9 to $\leq$ 15^{o}C, May and October; $\geq$ 19^{o}C, July to September, respectively).

Figure 4. Ordinations based on Bray-Curtis similarities of phytoplankton biovolumes, averaged across inner and outer Bays and/or sampling years and months. Absolute biomass for each of *Microcystis* and the centric diatom, *Cyclotella ocellata*, is superimposed (as symbols of differing size) upon ordinations.

Modeling Chlorophyll a Via Artificial Neural Networks (ANN)





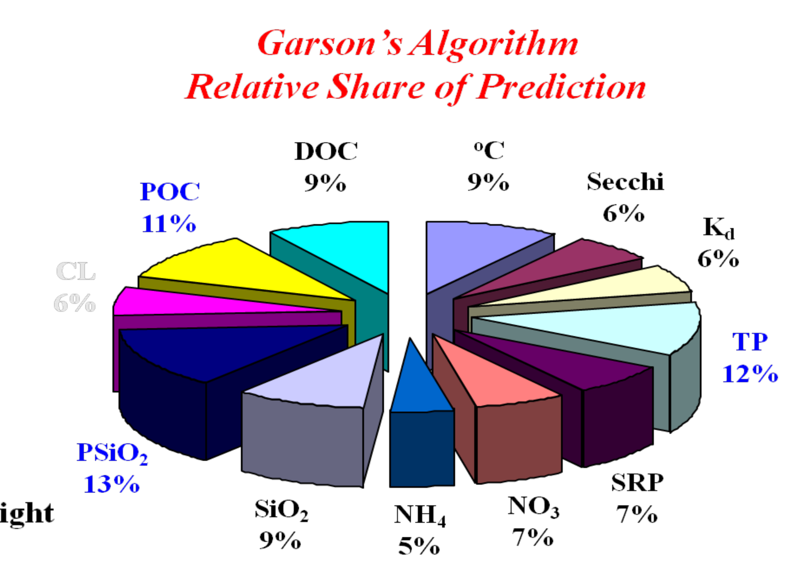


Figure 5. A Neural Interpretive Diagram for a trained artificial neural network (ANN) modeling total phytoplankton abundance, as chlorophyll a, and incorporating 12 hydrological variables as predictors.

Figure 6. Modeled chlorophyll a concentrations as a function of measured concentrations for a trained ANN. The solid line and corresponding statistical information represent the 'best' fit for the modeled:measured relationship, as derived from linear regression. The dashed line represents a 1:1 relationship.

Figure 7. The relative share of prediction associated with hydrological variables in modeling chlorophyll a concentrations, as determined using Garson's Algorithm.

Modeling *Microcystis* Via Non-Parametric Regression

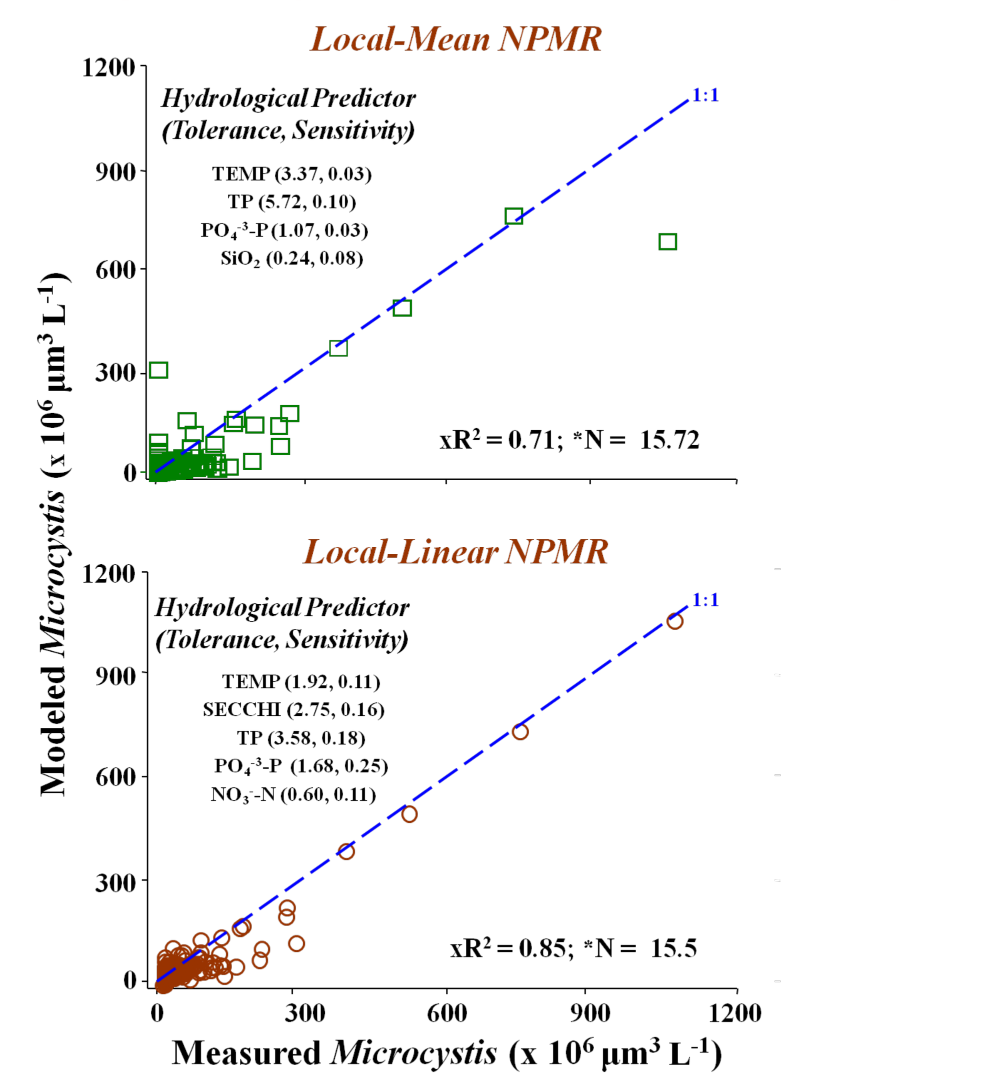


Figure 8. Modeled vs. measured biovolumes, from non-parametric multiplicative regressions (NPMR) of *Microcystis* biomass with hydrological predictors. Top) an optimal local-mean model. Predictor variables and associated tolerance/ sensitivity values are listed. Accompanying statistical information denotes the models' 'goodness of prediction' (as a 'cross-validated' regression coefficient, xR^2) and the mean, minimum neighborhood size (*N).

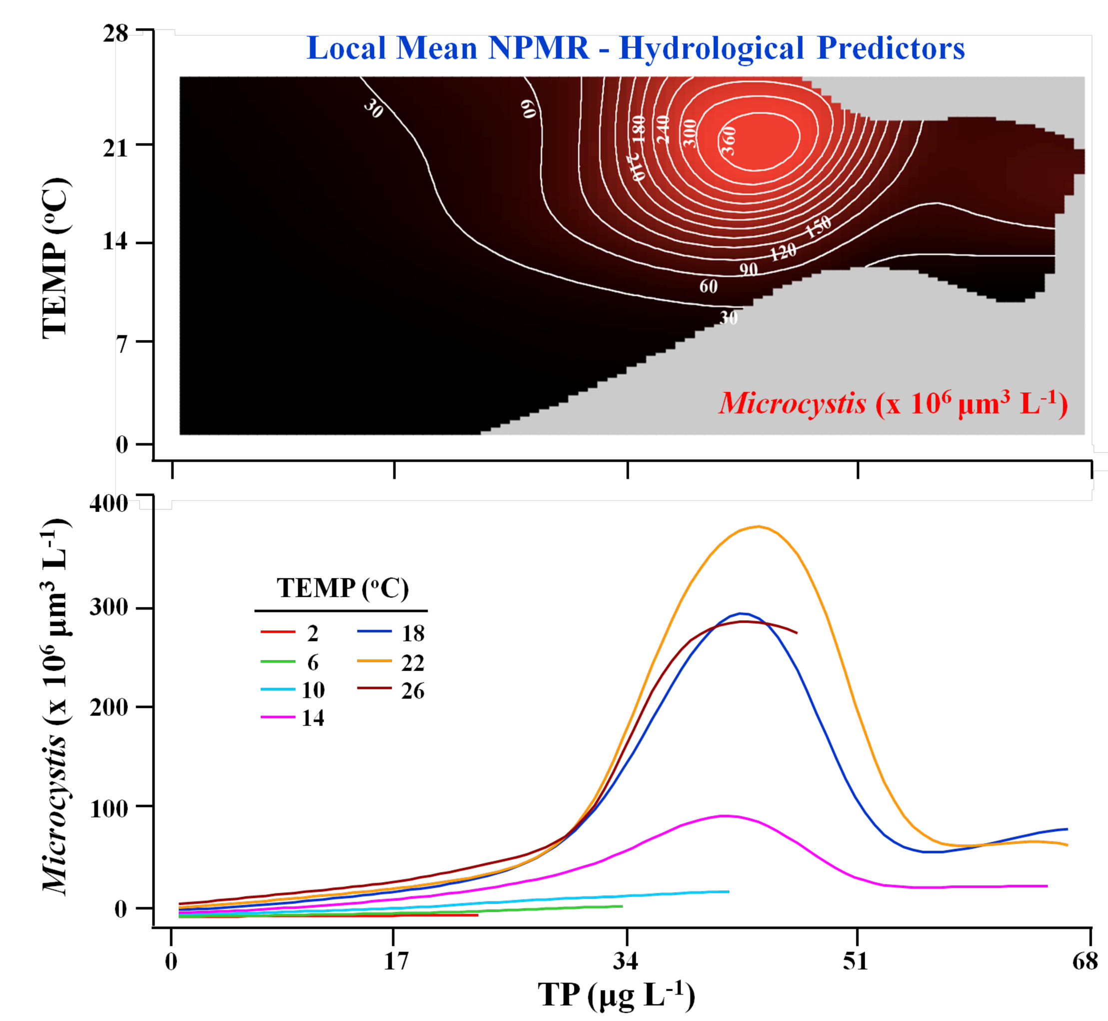


Figure 9. *Microcystis* response surfaces for a local-mean model (see top panel, Figure 8). Top) 3-D contour surface for modeled biovolumes (x 10^6 $\mu m^3 L^{-1}$) as a function of [TP] and water-column temperature. The black-red gradient and isopleths depict increasing biomass accumulations. Grey areas denotes where insufficient data to fit the model existed. Bottom) 2-D depiction of parallel 'slices' across the modeled response surface along the data range for [TP].

Matching Phytoplankton & Environmental Variables

Bay	Variable Combination (Spearman Rank Correlation; ρ)	
	Hydrological-Meteorological	Hydrological-Meteorological-River Loads'
Inner	Wind Speed, Temperature, [NO_3^--N], [POC], [$PSiO_2$] (0.42)	Wind Speed, River-$TP_{28+\ Day\ Lag}$, Temperature, [POC] (0.56)
Outer	Wind $Speed_{Day\ 0,-2\ Day\ Ave}$, Temperature, [$NO_3^-$-N], [POC], [$PSiO_2$] (0.51)	Wind Speed, River-$TP_{42+\ Day\ Lag}$, [NO_3^--N], Temperature, [POC], (0.56)

Acknowledgements

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